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Fish communities associated with cold-water corals vary with depth and substratum type

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ABSTRACT

Understanding the processes that drive the distribution patterns of organisms and the scales over which these processes operate are vital when considering the effective management of species with high commercial or conservation value. In the deep sea, the importance of scleractinian cold-water corals (CWCs) to fish has been the focus of several studies but their role remains unclear. We propose this may be due to the confounding effects of multiple drivers operating over multiple spatial scales. The aims of this study were to investigate the role of CWCs in shaping fish community structure and individual species-habitat associations across four spatial scales in the NE Atlantic ranging from "regions" (separated by >500 km) to "substratum types" (contiguous). Demersal fish and substratum types were quantified from three regions: Logachev Mounds, Rockall Bank and Hebrides Terrace Seamount (HTS). PERMANOVA analyses showed significant differences in community composition between all regions which were most likely caused by differences in depths. Within regions, significant variation in community composition was recorded at scales of c. 20–3500 m. CWCs supported significantly different fish communities to non-CWC substrata at Rockall Bank, Logachev and the HTS. Single-species analyses using generalised linear mixed models showed that *Sebastes* sp. was strongly associated with CWCs at Rockall Bank and that *Neocyttus helgae* was more likely to occur in CWCs at the HTS. Depth had a significant effect on several other fish species. The results of this study suggest that the importance of CWCs to fish is species-specific and depends on the broader spatial context in which the substratum is found. The precautionary approach would be to assume that CWCs are important for associated fish, but must acknowledge that CWCs in different depths will not provide redundancy or replication within spatially-managed conservation networks.

1. Introduction

Understanding how fish are distributed across marine landscapes is vital in establishing effective management strategies for their conservation and sustainable use. This is particularly true where management is to be largely based on spatially explicit management tools (e.g. Marine Protected Areas (MPAs); FAO, 2007). The deep sea is one such environment, with management measures increasingly targeted towards identifying and protecting Vulnerable Marine Ecosystems (VMEs; e.g. FAO, 2009). In Europe these measures have largely been introduced in response to the requirements of the Habitats Directive (Council Directive 92/43/EEC). Further spatial measures are being implemented due to the Marine Strategy Framework Directive (MFSD; 2008/56/EC), under which a far wider range of species and habitats must be considered through ecosystem-level approaches to management. Unfortunately, relatively little is understood about how deep-sea fish are spatially distributed over the seafloor, and there is therefore an urgent requirement for high quality data to inform management decisions.

Many deep-sea demersal fish species inhabiting the continental slopes (200–4000 m) are targeted by deep-water fisheries or captured as bycatch. Although deep-sea fish show a range of life-history traits (Drazen and Haedrich, 2012), they can be particularly vulnerable to over-exploitation if, for example, they have low fecundity or slow growth rates (Norse et al., 2012). Given the high mobility and potentially broad spatial ranges of deep-sea fish, studies examining their fine-scale distribution patterns are rare, and yet such data are vital in developing appropriate management plans for the conservation and sustainable management of fish stocks. However, if a fish species or community associates strongly

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with particular habitat features, then it may be possible to use those features as surrogates for fish distributions (e.g. Anderson et al., 2009). If those features are themselves of conservation importance, then it may be relatively simple to extend existing management objectives to include the requirements of the fish species.

Framework-forming cold-water corals (CWCs) are colonial, ahermatypic scleractinians and one of the most widespread taxa in the deep oceans (Roberts et al., 2006; Roberts et al., 2009). CWCs have a circumglobal distribution defined predominantly by depth, temperature and water chemistry (Roberts et al., 2006; Davies and Guinotte, 2011), and are believed to increase benthic habitat heterogeneity and biological diversity by providing "islands" of complex, hard substrata in an environment otherwise dominated by soft sediments (Buhl-Mortensen et al., 2010). However, as well as being ecologically valuable, CWCs are highly vulnerable to trawl damage (Hall-Spencer et al., 2002; Althaus et al., 2009). CWCs have therefore been recognised as VMEs and are a target of global conservation efforts in the High Seas (e.g. de Juan and Lleonart, 2010; Rengstorf et al., 2013). In European waters, they are listed as Annex 1 habitats under the Habitats Directive. If CWCs provide important substrata for deep-sea fish, closures to protect CWCs may also be a useful tool for the management of those species.

Despite increasing interest in understanding the importance of CWCs to fish, results published to date remain equivocal. In Norwegian waters, Mortensen et al. (1995) and Fosså et al. (2002) reported higher abundances of redfish (*Sebastes* spp.) over coral bioherms. Husebø et al. (2002) used long-lines and gillnets to capture higher numbers of redfish where CWCs were present, as well as larger sizes of redfish (*Sebastes* spp.), ling (*Molva molva*) and tusk (*Brosme brosme*) compared to areas where CWCs were absent, while Kutti et al. (2014) caught higher numbers of several commercially-important fish species where CWCs were present. Costello et al. (2005) used a range of methodologies to study fish associations with CWCs across eight regions of the NE Atlantic and found that although depth was the strongest predictor of community composition across the entire study area, areas containing CWCs generally supported a different fish fauna to those without CWCs, with a number of species-specific associations occurring within different regions. Soeffker et al. (2011) conducted two ROV video surveys across the Giant and Twin coral mounds (NE Atlantic), but only detected a significant effect of substratum type at the Giant Mound. Again however, they noted a small number of significant species-specific associations with CWCs. In the NW Atlantic, Ross and Quattrini (2007) provided one of the clearest demonstrations of CWC association by deep-water fish, reporting a unique and possibly obligate fish fauna occurring on coral mounds on the Blake Plateau. In the NE Pacific, Du Preez and Tunnicliffe (2011) reported close associations between *Sebastes* spp. and both CWCs and emergent epifauna (e.g. gorgonians and sponges).

Not all studies have demonstrated associations between CWCs and fish however. A long-term video study of individual species associations with CWCs in the Belgica Mound province of the NE Atlantic found no differences in either the abundance or biomass of fish associated with CWCs. Instead, physical variables such as depth were cited as the main predictors of distribution, though effects varied between sites (Biber et al., 2014). Long-lining (D'Onghia et al., 2012) and towed-video surveys (D'Onghia et al., 2011) conducted in the Santa Maria de Leuca CWC province in the Mediterranean Sea found no significant effect of CWCs on the overall fish community, though it was suggested that some taxa may use CWCs preferentially at different life stages. In the NW Atlantic, Auster (2005) found that coral substrata in the Gulf of Maine were functionally indistinguishable from substrata created by other large epifauna and did not support a distinct fish assemblage. Baker et al. (2012) examined fish abundance and community composition in three canyons in the Grand Banks region, but failed to find any association between fish abundance or community composition and CWCs, instead citing depth as the major influence. Stone (2006) noted that apparent associations could arise because certain fish and "habitat-forming" fauna share a preference for similar substrata leading to covariance which may be difficult to separate. The studies considered here include a diverse range of methodologies and taxa and cover a wide geographic range, but when taken together suggest that the distributions of fish within CWC areas may be influenced by a range of processes operating across multiple scales of organisation.

The importance of scale in ecological studies is well known (e.g. Levin, 1992; Chave, 2013). Patterns of both biodiversity (e.g. Levin et al., 2001; Buhl-Mortensen et al., 2010) and the habitat selection choices made by individuals (Morris, 1987; Mayor et al., 2009; Gaillard et al., 2010) are strongly influenced by spatial scale. Following their 2007 study, Ross and Quattrini (2009) determined that faunal associations at the Blake Plateau were driven primarily by depth and habitat structure over regional scales (700 km), though the nature of these relationships varied between sites. At fine scales, Quattrini et al. (2012) determined that other habitat characteristics were important to distributions of fish at the Blake Plateau, and their importance was specific to particular fish species. Linking fine-scale variability in habitat diversity and habitat-use patterns to broader scales that are appropriate for management use is likely to be important in understanding the high variability observed in fish associations with CWCs to date. However, the influence of multiple spatial scales has not yet been examined within a single study, which may lead to difficulties in extrapolating from one study to another due to differences in methodologies and temporal variation.

The aims of the present study were to examine the importance of CWCs in shaping the distribution patterns of demersal fish populations and communities and to determine how they may be influenced by the scale at which the analysis is conducted. The aims are addressed using opportunistically-collected ROV video footage from the NE Atlantic collected over four nested spatial scales and the data are used to provide recommendations for future management of deep-sea fish.

2. Study sites

The distributions of fish were studied in three regions of the NE Atlantic (Fig. 1): the Logachev Mounds (SE Rockall Bank), NW Rockall Bank and the Hebrides Terrace Seamount (HTS; continental slope). CWCs have previously been observed in all regions.

2.1. Logachev Mounds

The Logachev Mounds are located on south-eastern slope of the Rockall Bank, between c. 600–800 m and extend approximately 120 km along the slope edge (Kenyon et al., 2003). The mounds in this region support prolific "framework building reefs" (primarily of *Lophelia pertusa* and *Madrepora oculata*) containing extensive areas of living and dead framework. Parts of the Logachev Mound area have been closed to fishing (EC 41/2006; Fig. 1), but these lie outside the region studied here.

2.2. NW Rockall Bank

Small patches of *Lophelia pertusa* have been recorded from NW Rockall Bank between c. 220–350 m depth (Wilson, 1979a; Howell et al., 2009). Part of this area was closed to fisheries in 2006 (EC 41/2006; Fig. 1) and has since been recognised as an EU Site of